Addressing the Challenges of Emerging Vector-Borne Diseases in the United States

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Current state of VBDs in the U.S. – increasing cases (2004-2016)

- Between 2004 and 2016, more than 640,000 cases of VBDs were reported in the US.
- The number of reported cases of disease from mosquito, tick, and flea bites has more than tripled.
- Tick-borne diseases accounted for over 75% of reported VBD cases.
- Mosquito-borne disease epidemics happen more frequently.
- The reported data substantially underestimate actual disease occurrence (8 to 70 fold depending on the disease).


- Chikungunya and Zika viruses caused outbreaks in the US for the first time.
- Seven new tick-borne agents shown to infect people in the US.
- Discovery of exotic tick vector *Haemaphysalis longicornis*

More people at risk

- Global commerce moves mosquitoes, ticks, and fleas around the world.
- Infected travelers can introduce and spread novel pathogens globally.
- Mosquitoes and ticks move disease agents into new areas of the US, causing more people to be at risk.
- Changing climate and land-use patterns increase exposure to disease vectors
Reported nationally notifiable mosquito-borne*, tick-borne+, and flea-borne disease cases – US states and territories, 2004-2016

* Mosquito-borne case counts include both locally transmitted and travel-associated cases.
+ A total of 89 flea-borne disease cases (plague) were reported during 2004-2016, ranging from two cases in 2010 to 16 cases in 2015. The cases are not depicted on the figure.

Tick-Borne Diseases
Total tick-borne disease cases, United States, 2004 – 2017

<table>
<thead>
<tr>
<th>Year</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>22,527</td>
</tr>
<tr>
<td>2005</td>
<td>26,800</td>
</tr>
<tr>
<td>2006</td>
<td>23,770</td>
</tr>
<tr>
<td>2007</td>
<td>31,808</td>
</tr>
<tr>
<td>2008</td>
<td>39,993</td>
</tr>
<tr>
<td>2009</td>
<td>42,649</td>
</tr>
<tr>
<td>2010</td>
<td>34,890</td>
</tr>
<tr>
<td>2011</td>
<td>40,795</td>
</tr>
<tr>
<td>2012</td>
<td>40,119</td>
</tr>
<tr>
<td>2013</td>
<td>46,231</td>
</tr>
<tr>
<td>2014</td>
<td>43,654</td>
</tr>
<tr>
<td>2015</td>
<td>49,825</td>
</tr>
<tr>
<td>2016</td>
<td>48,610</td>
</tr>
<tr>
<td>2017</td>
<td>59,349</td>
</tr>
</tbody>
</table>
In 2017, a record number of cases of tick-borne disease were reported to CDC

<table>
<thead>
<tr>
<th>Reported Tick-borne diseases, U.S.</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lyme disease (confirmed and probable)</td>
<td>36,429</td>
<td>42,743</td>
</tr>
<tr>
<td>Anaplasmosis/Ehrlichiosis†</td>
<td>5,750</td>
<td>7,718</td>
</tr>
<tr>
<td>Spotted Fever Rickettsiosis§</td>
<td>4,269</td>
<td>6,248</td>
</tr>
<tr>
<td>Babesiosis§§</td>
<td>1,910 2</td>
<td>2,368</td>
</tr>
<tr>
<td>Tularemia</td>
<td>230</td>
<td>239</td>
</tr>
<tr>
<td>Powassan virus</td>
<td>22</td>
<td>33</td>
</tr>
<tr>
<td>Total</td>
<td>48,610</td>
<td>59,349</td>
</tr>
</tbody>
</table>

† Anaplasmosis and ehrlichiosis were reported separately after 2008 but are combined here for the entire period
§Includes R. rickettsii, R. parkeri, R. species 364D
§§ Babesiosis surveillance data are reported independently to different CDC programs. For this reason, surveillance data reported elsewhere might vary slightly from data reported in this summary
Reported Lyme Disease Cases by Year, U.S., 1991-2017

Cases

Year

1992
1997
2002
2007
2012
2017

Probable*
Confirmed

0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
Expanding geographic range of Lyme disease cases

Distribution of reported Lyme disease cases, 2001 and 2017

Source: cdc.gov/lyme/stats/index.html
Geographic expansion of ticks locations where *Ixodes scapularis* recorded

Discovery of tick-borne pathogens as causes of human disease by year, 1960–2016

- **Year** represents when tick-borne pathogen was recognized as cause of human disease.
Drivers of tick-borne disease emergence

- Reforestation
- Overabundant deer
- Expansion of suburbia into wooded areas
- Abundant habitat around homes for Lyme reservoir hosts
- Increased numbers of ticks
- Increased exposure opportunities in people
Haemaphysalis longicornis (Asian Longhorned Tick)

- Discovered in New Jersey in 2017, and now reported from ten U.S. states (Arkansas, Connecticut, Kentucky, Maryland, North Carolina, New Jersey, New York, Pennsylvania, Virginia, and West Virginia)
- Documented in 49 counties or county equivalents
- Reported from 15 animal species and from humans
- Pathogens found in these ticks in other parts of the world, that are enzootic in the U.S., include Borrelia, Anaplasma, Ehrlichia, Rickettsia, Babesia, and Theileria.
- Additional concerns about potential transmission of viral pathogens in the U.S., including Heartland and Powassan viruses
- Potential for broad U.S. distribution

Sources:

Mosquito-Borne Diseases
Recent arboviral disease outbreaks in the continental U.S.

**Vector Spotlight: Impact of Mosquito-Borne Diseases**

**West Nile Virus**
- Emerged: 1999 (New York)
- States most affected: California, Colorado, Texas, Illinois
- Potential outcomes: seizures, coma, paralysis, death

**Chikungunya Virus**
- Emerged: 2014 (Florida)
- States most affected: Texas, Florida, New York, California
- Potential outcomes: severe arthritis, nerve pain

**Dengue Virus**
- Re-emerged: 2015 (Hawaii)
- States most affected: Hawaii, Florida, Texas
- Potential outcomes: internal bleeding, death

**Zika Virus**
- Emerged: 2016 (Florida, Texas)
- States most affected: Florida, Texas, New York, California
- Potential outcomes: severe birth defects, microcephaly, fetal loss
Emergence of Zika Virus in the Americas, 2015 – 2016

May 2015
PAHO issued an alert regarding the first confirmed Zika virus infection in Brazil

January 22, 2016
CDC EOC activated in response to Zika outbreak in the Americas and increased reports of birth defects and Guillain-Barré syndrome in affected areas

February 1, 2016
WHO declares the Zika virus outbreak as a public health emergency of international concern (PHEIC); CDC elevates EOC to Level 1

July 29, 2016
Florida announces first cases of local transmission (Miami)
Emergence of Zika Virus in the Americas, 2016 – 2017

November 28, 2016
TX Dept of State Health Services reported the state’s first case of local mosquito-borne Zika virus infection in Brownsville, TX

June 2017
CDC removed the yellow area designation for Miami-Dade County, FL

August 2017
CDC lifted the yellow area designation for Brownsville, Texas

November 2016
WHO declared the end of Zika as a public health emergency of international concern

September 2017
CDC deactivated its response to Zika.
Zika Virus infection in the US states and territories, cumulative reported cases for 2015 – 2018*

<table>
<thead>
<tr>
<th>Category</th>
<th>US States (N=5,723)</th>
<th>US Territories (37,270)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel-related</td>
<td>5,437</td>
<td>147</td>
</tr>
<tr>
<td>Local transmission</td>
<td>231</td>
<td>37,123</td>
</tr>
<tr>
<td>Other routes</td>
<td>55</td>
<td>0</td>
</tr>
<tr>
<td>Laboratory transmission</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Sexual transmission</td>
<td>52</td>
<td>-</td>
</tr>
<tr>
<td>Person-to-person through unknown route</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

*Cumulative provisional reported cases from January 1, 2015 through September 5, 2018
West Nile virus neuroinvasive disease incidence reported to CDC, by year, 1999-2017

Source: https://www.cdc.gov/westnile/statsmaps/cumMapsData.html#one
Number of WNV neuroinvasive disease cases by week of illness onset – United States, 1999–2017
Average annual incidence of WNV neuroinvasive disease by county – United States, 1999–2017
Comparison of County Population and Average Annual Number of WNV Neuroinvasive Disease Cases

County Population

Neuroinvasive Disease Cases
West Nile virus infections and illnesses – estimated numbers, 1999-2017

22,999 neuroinvasive disease reported

690,000-1,380,000 estimated symptomatic cases (30-60 times neuroinvasive disease cases)

3.4-6.9 million estimated infections (150-300 times neuroinvasive disease cases)
Yellow fever risk in Brazil, 2016 – 2018

Source: http://portalms.saude.gov.br/saude-de-a-z/febre-amarela-sintomas-transmissao-e-prevencao/situacao-epidemiologica-dados
Key Challenges
Key challenges: Mosquito-borne diseases

• Vector control
  – Lack of proven control measures for *Aedes aegypti* (dengue, yellow fever, Zika, chikungunya)
  – Patchwork of vector-control operations with varying capacities
    • 84% lack at least one of five core capacities\(^1\)
  – Insecticide resistance likely widespread
    • No new classes of public health pesticide in >50 years!

• Surveillance and response
  – Surveillance infrastructure diminishing, particularly vector surveillance
  – Eroding technical capacities at all levels; shrinking entomologic workforce
  – Public acceptance of emergency control measures – communication challenge
  – Delayed or ineffective response to outbreaks

Reported number of cases of WNV neuroinvasive disease, by calendar week, Dallas county, 2012

Adapted from JAMA 2013;310:297-307
Number of cases of WNV neuroinvasive disease, by calendar week of disease onset and report, Dallas county, 2012

Adapted from JAMA 2013;310:297-307
Number of cases of WNV neuroinvasive disease, by calendar week of onset and report, and vector index, Dallas county, 2012

Adapted from JAMA 2013;310:297-307
Key challenges: Mosquito-borne diseases

• Clinical care
  – No therapeutics for any viral vector-borne disease
  – Under-diagnosis
  – Need for improved serological tests for flaviviruses (cross reactivity of dengue and Zika is a particular problem)

• Prevention
  – No approved vaccine for any endemic arbovirus (e.g., West Nile)
  – Need to augment repellent use
  – Need for non-pesticide vector reduction measures (e.g., sterile insect approach).
  – Regulatory and public perception issues.
Key challenges: Tick-borne diseases

• **Tick control**
  – No proven community control method for any domestic tick-borne disease (with exception of RMSF on Indian reservations in Arizona)
  – Proving efficacy difficult: Need for both entomological and human disease outcomes – large studies lasting several years needed. At the current pace of investigation, will likely take decades to find an effective community control measure and implement it.

• **Surveillance and response**
  – Eroding technical capacities at all levels; shrinking entomologic workforce

• **Prevention**
  – No approved vaccine for Lyme disease
  – Need to augment personal protective measures (e.g., repellent use, tick checks)
Effectiveness of Residential Acaricides to Prevent Lyme and Other Tick-borne Diseases in Humans

Alison F. Hinckley,1 James I. Meek,2 Julie A. E. Ray,2,a Sara A. Niesobacki,2 Neeta P. Connolly,2 Katherine A. Feldman,4 Erin H. Jones,4,a P. Bryon Backenson,5 Jennifer L. White,5 Gary Lukacik,5 Ashley B. Kay,1,a Wilson P. Miranda,5 and Paul S. Mead1

1Division of Vector-Borne Diseases, Centers for Disease Control and Prevention, Fort Collins, Colorado; 2Connecticut Emerging Infections Program, Yale School of Public Health, New Haven, and 3Western Connecticut State University, Danbury; 4Maryland Department of Health and Mental Hygiene, Baltimore; and 5New York State Department of Health, Albany

(See the editorial commentary by Schiffman, Neitzel, and Lynfield on pages 171-2.)

Background. In the northeastern United States, tick-borne diseases are a major public health concern. In controlled studies, a single springtime application of acaricide has been shown to kill 68%–100% of ticks. Although public health authorities recommend use of acaricides to control tick populations in yards, the effectiveness of these pesticides to prevent tick bites or human tick-borne diseases is unknown.

Methods. We conducted a 2-year, randomized, double-blinded, placebo-controlled trial among 2727 households in 3 northeastern states. Households received a single springtime barrier application of bifenthrin or water according to recommended practices. Tick drags were conducted 3–4 weeks after treatment on 10% of properties. Information on human–tick encounters and tick-borne diseases was collected through monthly surveys; reports of illness were validated by medical record review.

Results. Although the abundance of questing ticks was significantly lower (63%) on acaricide-treated properties, there was no difference between treatment groups in human–tick encounters, self-reported tick-borne diseases, or medical-record-validated tick-borne diseases.

Conclusions. Used as recommended, acaricide barrier sprays do not significantly reduce the household risk of tick exposure or incidence of tick-borne disease. Measures for preventing tick-borne diseases should be evaluated against human outcomes to confirm effectiveness.

Keywords. Lyme disease; tick-borne diseases; ticks; prevention; pesticide; acaricide; humans.

Key challenges: Tick-borne diseases

• **Diagnostics**
  – Inappropriate diagnostic test ordering and interpretation (e.g., Lyme IgM in people with symptoms >30 days; Western blot without positive ELISA; insufficient risk and clinical correlation)
  – Need to simplify diagnostic algorithm: C6 test and two ELISA regimen
  – Use of inadequately validated and non-FDA approved tests

• **Clinical care**
  – Chronic Lyme disease
  – Competing guidelines
  – Misinformation
  – Legal issues
  – Misdiagnosis or underdiagnosis (Lyme, SFGR)
  – Delay in treatment or inappropriate treatment (Lyme, SFGR)
Key challenge: Sustainability

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Lyme</th>
<th>VBD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>$40.3</td>
<td>$7.38</td>
<td>$33.0</td>
</tr>
<tr>
<td>2003</td>
<td>$43.8</td>
<td>$7.13</td>
<td>$36.7</td>
</tr>
<tr>
<td>2004</td>
<td>$40.2</td>
<td>$5.61</td>
<td>$34.6</td>
</tr>
<tr>
<td>2005</td>
<td>$43.3</td>
<td>$5.57</td>
<td>$37.8</td>
</tr>
<tr>
<td>2006</td>
<td>$50.4</td>
<td>$5.43</td>
<td>$44.9</td>
</tr>
<tr>
<td>2007</td>
<td>$32.1</td>
<td>$5.36</td>
<td>$26.7</td>
</tr>
<tr>
<td>2008</td>
<td>$31.5</td>
<td>$5.27</td>
<td>$26.3</td>
</tr>
<tr>
<td>2009</td>
<td>$31.5</td>
<td>$8.94</td>
<td>$26.3</td>
</tr>
<tr>
<td>2010</td>
<td>$35.6</td>
<td>$5.27</td>
<td>$26.7</td>
</tr>
<tr>
<td>2011</td>
<td>$32.0</td>
<td>$8.77</td>
<td>$23.2</td>
</tr>
<tr>
<td>2012</td>
<td>$31.8</td>
<td>$8.72</td>
<td>$23.0</td>
</tr>
<tr>
<td>2013</td>
<td>$30.1</td>
<td>$8.26</td>
<td>$21.8</td>
</tr>
<tr>
<td>2014</td>
<td>$37.0</td>
<td>$10.6</td>
<td>$26.4</td>
</tr>
<tr>
<td>2015</td>
<td>$35.0</td>
<td>$10.6</td>
<td>$24.4</td>
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<td>2016</td>
<td>$37.0</td>
<td>$10.7</td>
<td>$26.4</td>
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<tr>
<td>2017</td>
<td>$37.1</td>
<td>$10.7</td>
<td>$26.4</td>
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<tr>
<td>2018</td>
<td>$49.3</td>
<td>$12.0</td>
<td>$38.6</td>
</tr>
<tr>
<td>2019</td>
<td>$50.6</td>
<td>$12.0</td>
<td>$38.6</td>
</tr>
</tbody>
</table>
Addressing challenges
A coordinated strategy for vector-borne threats

Advance Innovation & Discovery

- Cutting edge diagnostic tools for the fast and accurate detection of vector-borne infections
- Identification of new and emerging vector-borne diseases & increased understanding of existing vector-borne threats
- R&D to develop ways to monitor and prevent insecticide resistance and foster new vector control technologies

Build Comprehensive Vector Programs

- A skilled vector workforce that can respond to the full variety of pathogens and the vectors that transmit them
- Robust state and local vector control programs that can identify and mobilize for action against existing and emerging threats
Division of Vector-Borne Diseases

VISION: Create a future where vector-borne diseases no longer threaten public health

MISSION: Reduce illness and death due to vector-borne diseases

Goal 1: Identify and detect vector-borne pathogens that cause disease in people
- Strategy 1: Discover and characterize vector-borne disease agents and their clinical manifestations
- Strategy 2: Improve diagnostics for vector-borne disease agents
- Strategy 3: Provide diagnostic support for public health partners, including providing reagents, tests, technical assistance, and maintaining reference collections
- Strategy 4: Disseminate findings to public health partners and the public

Goal 2: Understand when, where, how often and how people are exposed to vector-borne pathogens
- Strategy 1: Improve and support surveillance systems for vector-borne diseases
- Strategy 2: Conduct field and laboratory studies to better understand where and how vector-borne pathogens are maintained and transmitted
- Strategy 3: Identify risk factors for exposure to vector-borne pathogens and develop risk predictions and decision support tools
- Strategy 4: Disseminate findings to public health partners and the public
Division of Vector-Borne Diseases

VISION: Create a future where vector-borne diseases no longer threaten public health

MISSION: Reduce illness and death due to vector-borne diseases

Goal 3: Prevent exposure to vector-borne pathogens and mitigate consequences of infection
  • Strategy 1: Develop and evaluate safe and effective vector control and vector-borne disease prevention strategies
  • Strategy 2: Provide evidence-based recommendations on the diagnosis, treatment and management of vector-borne diseases
  • Strategy 3: Respond to public health emergencies

Goal 4: Implement vector-borne disease diagnostics, surveillance, control and prevention programs developed in goals 1-3
  • Strategy 1: Strengthen capacity to implement safe and effective vector-borne disease diagnostics, surveillance, control, and prevention programs
  • Strategy 2: Translate/adapt public health tools for programmatic implementation at local, tribal, territorial, state, and international levels
  • Strategy 3: Disseminate effective public health programs (including communications)
  • Strategy 4: Monitor, evaluate, and further adapt public health programs
CDC investments toward a systems approach for vector-borne disease preparedness

New and/or enhanced programs in 2017-2018

• Strong intramural program focusing on improved diagnostics and surveillance and interventional research
• State-based vector borne disease activities (ELC)
• VBD Centers of Excellence (CoEs)
• Contracts (BAA mechanism) to support innovative vector control tools and improved diagnostics for Zika virus
• Puerto Rico Vector Control Unit
• Training contracts and interagency agreements (AMCA, ESA, CSTE, NACCHO, BARDA, etc.)
• Establishment of national surveillance systems for mosquitoes and ticks
• Other research collaborations and technical assistance
CDC Regional Centers of Excellence for Vector-Borne Diseases

• Established in 2017 with Zika funding – $48M for 5 regional centers for 5 years:
  – Northeast Regional Center – New York
  – Midwest Regional Center – Wisconsin
  – Pacific Southwest Center – California
  – Western Gulf Center – Texas
  – Southeastern Regional Center – Florida

• Program goals:
  – Building effective collaboration between academic communities and public health organizations at federal, state, and local levels for surveillance, prevention, and response
  – Training public health entomologists in the knowledge and skills required to address vector-borne disease concerns
  – Conducting applied research to develop and validate effective prevention and control tools and methods and to anticipate and respond to disease outbreaks
Developing a national strategy
“A concerted, sustained national effort is needed to address existing problems and to reverse the upward trend of VBD incidence.”

“The response will require coordination across a national network of collaborators operating under a common national strategy.”
Key Components of a National Strategy for Vector-Borne Disease Prevention and Control

An effective public health response to vector-borne disease relies upon a well-communicated and coordinated strategy...
Vector-borne disease prevention and control – system map

- Centers for Disease Control and Prevention
- Other Federal Agencies (NIH, USDA, FDA, EPA, DoD, etc.)
- University and Commercial Innovators
- Regional Centers of Excellence
- Partner Organizations (APHL, ASTHO, CSTE, NACCHO, AMCA, ESA, IDSA, AMA, etc.)
- State Health Departments
  - Local Health Departments
    - Local Vector Control Organizations
  - Community Members

Funded Relationship
Technical Assistance
Available tools and resources
CDC tools and resources – mosquitoes

WNV home page: https://www.cdc.gov/westnile/index.html

WNV prevention page: https://www.cdc.gov/westnile/prevention/index.html


Dengue home page: https://www.cdc.gov/Dengue/

NCEH Environmental Health Services web page: https://www.cdc.gov/nceh/ehs/activities/vector-control.html
CDC tools and resources – ticks

Tick home page: https://www.cdc.gov/ticks/index.html

Tick identification page: https://www.cdc.gov/ticks/tickborne-diseases/tickID.html


Lyme home page: https://www.cdc.gov/lyme/index.html

Prevention tool kit: https://www.cdc.gov/lyme/toolkit/index.html

NCEH Environmental Health Services web page: https://www.cdc.gov/nceh/ehs/activities/vector-control.html
Summary and Conclusions

• VBDs are increasing in the US, both in incidence and in distribution.
• The factors that are driving VBD introduction and emergence vary among diseases but are NOT likely to cease, indicating that current trends will continue and likely worsen.
• There are a number of challenges to preventing VBDs, including the lack of vaccines and effective vector control tools, insecticide resistance, and eroding technical capacities in public health entomology at federal, state and local levels.
• A national strategy is needed to address VBD threats and to reverse the alarming trend in morbidity and mortality associated with these diseases.
Thank you and questions

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The findings and conclusions in this report are those of the author and do not necessarily represent the official position of the Centers for Disease Control and Prevention